

Case Study

Open Access

Evaluating the Application Effects of Alternate Wetting and Drying (AWD) Irrigation in Rice Cultivation

Zhongxian Li, Ruchun Chen, Haiying Huang ✉

Hier Rice Research Center, Hainan Institute of Tropical Agricultural Resources, Sanya, 572025, Hainan, China

✉ Corresponding email: haiying.huang@hitar.orgRice Genomics and Genetics, 2025, Vol.16, No.5 doi: [10.5376/rgg.2025.16.0022](https://doi.org/10.5376/rgg.2025.16.0022)

Received: 27 Jul., 2025

Accepted: 06 Sep., 2025

Published: 20 Sep., 2025

Copyright © 2025 Li et al., This is an open access article published under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Preferred citation for this article:

Li Z.X., Chen R.C., and Huang H.Y., 2025, Evaluating the application effects of alternate wetting and drying (AWD) irrigation in rice cultivation, Rice Genomics and Genetics, 16(5): 254-259 (doi: [10.5376/rgg.2025.16.0022](https://doi.org/10.5376/rgg.2025.16.0022))

Abstract This study systematically evaluated the application effects of Alternate Wetting and Drying (AWD) irrigation technology in rice cultivation, with a focus on its role in improving water use efficiency, maintaining yield stability, enhancing grain quality, and reducing environmental impacts. Field experiments were conducted in two representative rice-growing regions in China-Xinghua in Jiangsu Province and Guanghan in Sichuan Province-to compare the performance of AWD and conventional continuous flooding under varying ecological and agronomic conditions. The results showed that AWD significantly reduced irrigation water consumption while maintaining or slightly increasing yield, and effectively mitigated greenhouse gas emissions, demonstrating a strong synergy between water saving and emission reduction. By integrating agronomic performance with ecological benefits, this study clarified the practical value and strategic significance of AWD technology in building a climate-resilient and resource-efficient rice production system. The findings aim to provide theoretical guidance and technical support for advancing sustainable and efficient rice farming, and promoting the development of water-saving agriculture.

Keywords Rice cultivation; Alternate wetting and drying (AWD); Water use efficiency; Greenhouse gas mitigation; Sustainable agriculture

1 Introduction

Rice cultivation is a critical agricultural activity, providing a staple food source for over half of the global population. However, traditional irrigation practices in rice farming, such as continuous flooding (CF), pose significant challenges, particularly concerning water use efficiency and environmental sustainability. Rice fields are among the largest consumers of freshwater resources and are significant contributors to greenhouse gas emissions, particularly methane (CH₄) and nitrous oxide (N₂O) (Carrizo et al., 2017; Sriphirom et al., 2019; Gao et al., 2024). These challenges necessitate the exploration of alternative irrigation methods that can conserve water and reduce emissions without compromising rice yields.

Alternate Wetting and Drying (AWD) irrigation has emerged as a promising water-saving technique in rice cultivation. This method involves periodic drying of the rice fields, allowing the water level to drop below the soil surface before re-irrigation. The theoretical basis of AWD is rooted in its potential to enhance water use efficiency and reduce methane emissions by introducing aerobic soil conditions intermittently during the growing season (Carrizo et al., 2017; Song et al., 2019; Zhang et al., 2023). Over the years, AWD has evolved with varying thresholds and management practices to optimize its benefits, such as maintaining soil water potential above certain levels to prevent yield loss (Zhao et al., 2024).

This study will evaluate the effectiveness of AWD irrigation in specific regions, focusing on its impact on water use, rice yield, and greenhouse gas emissions, and gain insight into the feasibility and benefits of adopting AWD as a standard practice for rice cultivation, thereby providing a reference for policies and practices in similar agricultural settings.

2 AWD Irrigation Technology: Principles and Implementation

2.1 Definition and water depth control methods

Alternate Wetting and Drying (AWD) is an irrigation practice designed to reduce water usage in rice cultivation by allowing the soil to dry out to a certain extent before re-irrigation. This method contrasts with continuous flooding, where fields are kept submerged throughout the growing season. AWD involves monitoring the water depth and allowing it to drop below the soil surface to a predetermined level before reapplying water. The water depth control is crucial, as it determines the frequency and amount of irrigation needed. For instance, in some studies, water levels are allowed to drop 10, 20, or 30 cm below the ground before re-irrigation. The optimal water potential for AWD is often maintained at pressures greater than -15 kPa, with water depths less than 18.5 cm during the rice growing season (Figure 1) (Zhang et al., 2023).

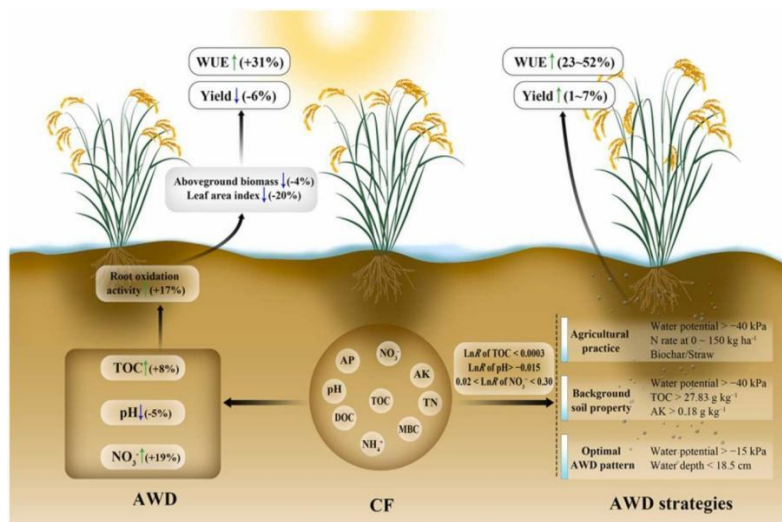


Figure 1 Alternate wetting and drying irrigation (AWD) (Adopted from Zhang et al., 2023)

2.2 Implementation requirements and field infrastructure

Implementing AWD requires specific field infrastructure and management practices. Fields must be equipped with tools to measure water depth accurately, such as field water tubes or simple observation wells. These tools help farmers determine when to irrigate based on the water level. Additionally, the field must be leveled properly to ensure uniform water distribution and prevent waterlogging in certain areas. The infrastructure should also support efficient water delivery and drainage systems to facilitate the alternate wetting and drying cycles (Gilardi et al., 2023; Wijesundara, 2024). In regions with shallow aquifers, the interaction between irrigation and groundwater recharge must be considered to maintain overall irrigation efficiency (Gilardi et al., 2023).

2.3 Irrigation scheduling across rice growth stages

AWD irrigation scheduling is tailored to the different growth stages of rice, ensuring that water is applied when it is most needed. During the early stages of rice growth, fields may be kept flooded to suppress weeds and support seedling establishment. As the rice plants mature, the AWD method is employed, allowing the soil to dry to the specified depth before re-irrigation. This cycle is repeated throughout the growing season, with adjustments made based on weather conditions, soil type, and crop needs (Carrijo et al., 2017; Cheng et al., 2022). The scheduling must be flexible to accommodate variations in environmental conditions and to optimize water use efficiency without compromising yield (Gao et al., 2024).

3 Case Study Region and Field Application

3.1 Xinghua, Jiangsu—AWD in a rice-wheat rotation system

In Xinghua, Jiangsu, the application of Alternate Wetting and Drying (AWD) irrigation in a rice-wheat rotation system has shown promising results. The AWD technique is particularly beneficial in regions with water scarcity, as it reduces water consumption while maintaining rice yields. Studies have demonstrated that AWD can decrease water use by 25%-70% compared to traditional continuous flooding methods, without significantly impacting rice

yield (Mishfaq et al., 2020; artínez-Eixarch et al., 2021). This makes AWD a viable option for sustainable rice cultivation in Jiangsu, where water resources are limited.

3.2 Guanghan, Sichuan—AWD ecological benefits in a double rice cropping system

In Guanghan, Sichuan, the implementation of AWD in a double rice cropping system has highlighted several ecological benefits. The technique not only conserves water but also reduces methane emissions, a significant contributor to greenhouse gases from rice fields (Malumpong et al., 2020; Martínez-Eixarch et al., 2021). The reduction in methane emissions is particularly important in addressing climate change impacts. Additionally, AWD has been shown to improve water productivity, making it an eco-friendly alternative to continuous flooding (Patikorn et al., 2018; Ishfaq et al., 2020). These ecological benefits make AWD a suitable irrigation strategy for the double rice cropping systems prevalent in Sichuan.

3.3 Comparative Insights and Practical Implications

Comparing the application of AWD in Xinghua and Guanghan reveals several insights. Both regions benefit from reduced water usage and improved water productivity, which are crucial in areas facing water scarcity (Patikorn et al., 2018; Wijesundara, 2024). However, the ecological benefits, such as reduced methane emissions, are more pronounced in Guanghan due to the double cropping system (Malumpong et al., 2020). Practically, the adoption of AWD requires careful management to ensure water levels are maintained appropriately, as variations can impact yield and environmental benefits (Martínez-Eixarch et al., 2021; Duong et al., 2024). The successful implementation of AWD in these regions underscores its potential as a sustainable irrigation practice that balances water conservation with agricultural productivity.

4 Effects on Water Use and Irrigation Efficiency

4.1 Change in total irrigation volume

Alternate Wetting and Drying (AWD) irrigation significantly reduces the total volume of water used in rice cultivation compared to continuous flooding (CF). Studies have shown that AWD can decrease irrigation water usage by approximately 33.88% globally, highlighting its potential as a water-saving technique (Gao et al., 2024). In Nepal, AWD plots received 57% less irrigation water than CF plots without a significant difference in yield, indicating a substantial reduction in water use (Howell et al., 2015). Similarly, in Italy, AWD was found to require less water from June onwards compared to continuous flooding, while still maintaining groundwater recharge (Gilardi et al., 2023).

4.2 Field seepage and evaporation comparisons

AWD irrigation affects field seepage and evaporation differently than continuous flooding. In the Mid-South United States, AWD did not result in decreased gross primary production (GPP), evapotranspiration (ET), or transpiration (T), suggesting that the periodic drying associated with AWD does not negatively impact these processes (Reavis et al., 2024). This indicates that AWD can maintain similar levels of field seepage and evaporation as CF, while using less water overall.

4.3 Improvement in water use efficiency (WUE)

AWD irrigation has been shown to improve water use efficiency (WUE) in rice cultivation. In China, AWD increased WUE by 25.3% to 28.9% across different rice cultivars, primarily due to enhanced root and shoot growth and development (Chu et al., 2016). A global meta-analysis also reported that AWD enhances WUE by 20.27% and irrigation water use efficiency by 47.58% (Gao et al., 2024). In Bangladesh, AWD treatments demonstrated higher WUE compared to continuous flooding, with treatment T1 achieving a WUE of 41.86 kg/ha/cm, compared to 38.64 kg/ha/cm for the control.

5 Impact on Rice Growth and Yield

5.1 Tiller number and plant height trends

Alternate Wetting and Drying (AWD) irrigation has shown varied effects on tiller number and plant height in rice cultivation. In a study conducted in Nepal, it was observed that tillering was significantly higher under AWD compared to continuous flooding (CF), although leaf elongation rates did not differ between treatments (Howell et

al., 2015). Similarly, in a study from Indonesia, rice grown under AWD with water media and rice husk showed the highest plant height and number of stems, indicating a positive impact on vegetative growth (Damanhuri et al., 2022). These findings suggest that AWD can enhance certain growth parameters, potentially leading to more robust plant development.

5.2 Dry matter accumulation and photosynthetic response

AWD irrigation can influence dry matter accumulation and photosynthetic efficiency in rice plants. The method has been associated with increased root activity, which can enhance nutrient uptake and photosynthetic response (Song et al., 2020). This is supported by findings from a meta-analysis indicating that AWD can maintain or even improve photosynthetic efficiency under certain conditions, despite reduced water inputs (Carrijo et al., 2017). The increased root activity under AWD may contribute to better dry matter accumulation, supporting overall plant growth and yield.

5.3 Yield components

The impact of AWD on yield components such as panicle number, grain weight, and seed setting rate varies across studies. In Nepal, AWD did not significantly affect yield components in one rice cultivar, while in another, a decrease in filled grain number was offset by an increase in effective tillers per hill (Howell et al., 2015). In Bangladesh, AWD treatments resulted in slightly lower grain yields compared to continuous flooding, but with improved water use efficiency. In contrast, a study in Tamil Nadu, India, reported higher yields under AWD compared to conventional methods, highlighting the potential for AWD to enhance yield components under specific conditions. These findings indicate that while AWD can reduce water use, its effects on yield components can vary depending on local conditions and rice varieties.

6 Environmental and Soil Health Impacts

6.1 Soil redox conditions and microbial activity

Alternate Wetting and Drying (AWD) irrigation significantly influences soil redox conditions and microbial activity. AWD alters the soil's redox potential, which can enhance microbial diversity and activity, leading to improved nutrient bioavailability. Studies have shown that AWD increases the total concentration and bioavailability of essential nutrients such as nitrogen, phosphorus, and potassium by 16%-54% compared to continuous flooding (CF) systems. This is attributed to the dynamic changes in soil moisture and redox conditions that favor microbial processes, enhancing nutrient cycling and availability. The presence of diverse microbial communities, including *Bacillus* and *Pseudomonas* species, is more pronounced under AWD, contributing to better nutrient modulation and plant growth (Majumdar et al., 2023).

6.2 GHG emission dynamics (methane and nitrous oxide)

AWD irrigation has a complex impact on greenhouse gas (GHG) emissions, particularly methane (CH₄) and nitrous oxide (N₂O). AWD significantly reduces CH₄ emissions by 47%-51.6% compared to CF, due to the intermittent drying periods that limit anaerobic conditions favorable for methanogenesis (Ishfaq et al., 2020). However, this reduction in CH₄ is often accompanied by an increase in N₂O emissions, ranging from 44% to 280%, as the aerobic conditions during drying phases promote nitrification and denitrification processes (Liao et al., 2020; Zhao et al., 2024). Despite the increase in N₂O emissions, the overall global warming potential (GWP) is reduced under AWD due to the substantial decrease in CH₄ emissions (Gao et al., 2024).

6.3 Soil structure and organic matter retention

AWD irrigation can positively affect soil structure and organic matter retention. The practice of AWD helps maintain or even improve soil organic carbon (SOC) levels, which are crucial for soil health and structure. Studies indicate that maintaining SOC levels above 12 g/kg is beneficial for minimizing yield losses and enhancing soil structure under AWD conditions (Gao et al., 2024). Additionally, AWD can improve soil aggregation and porosity, which are essential for root growth and water infiltration, thereby supporting sustainable rice production (Zhang et al., 202). The dynamic wetting and drying cycles in AWD promote the retention of organic matter, which is vital for long-term soil fertility and productivity.

7 Concluding Remarks

Alternate Wetting and Drying (AWD) irrigation has been shown to significantly impact rice cultivation by enhancing water use efficiency and reducing water consumption without substantially compromising yield. Studies indicate that AWD can reduce water use by 19%-56% compared to conventional flooding methods, while maintaining or slightly reducing rice yields. Additionally, AWD has been associated with a reduction in greenhouse gas emissions, particularly methane, by up to 100% in some cases, contributing to a lower global warming potential. However, there is a potential yield penalty, with some studies reporting a decrease in yield by approximately 5.4% under certain conditions.

The large-scale application of AWD presents several opportunities, including improved water management and reduced environmental impact, which are crucial in regions facing water scarcity. AWD's ability to maintain groundwater recharge while reducing irrigation needs makes it a viable option for sustainable rice production. However, constraints include the need for precise water management and monitoring, which can be challenging for farmers without access to adequate resources or training. Additionally, the variability in yield response and the potential for increased nitrous oxide emissions under certain conditions pose challenges that need to be addressed.

To optimize irrigation practices, future research should focus on developing integrated management strategies that combine AWD with other sustainable practices, such as biochar application and optimized nutrient management, to enhance soil health and further reduce emissions. It is also recommended to conduct long-term studies across diverse agro-ecological zones to better understand the adaptability and long-term benefits of AWD. Policymakers should consider supporting infrastructure development and farmer training programs to facilitate the adoption of AWD on a larger scale, ensuring that farmers have the necessary tools and knowledge to implement this practice effectively.

Acknowledgments

We thank Mr Z. Xu from the Institute of Life Science of Jiyang College of Zhejiang A&F University for his reading and revising suggestion.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

References

- Damanhuri, Widodo T., and Muhklisin I., 2022, Effect of soilless media with alternate wetting-drying (AWD) as basic irrigation on the growth of two varieties of rice, IOP Conference Series: Earth and Environmental Science, 980: 012054.
<https://doi.org/10.1088/1755-1315/980/1/012054>
- Carrijo D., Lundy M., and Linquist B., 2017, Rice yields and water use under alternate wetting and drying irrigation: a meta-analysis, Field Crops Research, 203: 173-180.
<https://doi.org/10.1016/J.FCR.2016.12.002>
- Cheng H., Shu K., Zhu T., Wang L., Liu X., Cai W., Qi Z., and Feng S., 2022, Effects of alternate wetting and drying irrigation on yield, water and nitrogen use, and greenhouse gas emissions in rice paddy fields, Journal of Cleaner Production, .
<https://doi.org/10.1016/j.jclepro.2022.131487>
- Chu G., Zhan M., Zhu K., Wang Z., and Yang J., 2016, Effects of alternate wetting and drying irrigation on yield and water use efficiency of rice, Acta Agronomica Sinica, 42: 1026.
<https://doi.org/10.3724/SP.J.1006.2016.01026>
- Duong N., Pham V., Le H., Nguyen S., and Huynh D., 2024, Evaluating the performance of alternate wetting and drying irrigation technology: an on-farm rice case study in An Giang Province, the Mekong Delta of Vietnam, Pertanika Journal of Tropical Agricultural Science, 47(3): 2.
<https://doi.org/10.47836/pjtas.47.3.02>
- Gao R., Zhuo L., Duan Y., Yan C., Yue Z., Zhao Z., and Wu P., 2024, Effects of alternate wetting and drying irrigation on yield, water-saving, and emission reduction in rice fields: a global meta-analysis, Agricultural and Forest Meteorology, 353: 110075.
<https://doi.org/10.1016/j.agrformet.2024.110075>
- Gilardi G., Mayer A., Rienznner M., Romani M., and Facchi A., 2023, Effect of alternate wetting and drying (AWD) and other irrigation management strategies on water resources in rice-producing areas of Northern Italy, Water, 15(12): 2150.
<https://doi.org/10.3390/w15122150>

- Howell K., Shrestha P., and Dodd I., 2015, Alternate wetting and drying irrigation maintained rice yields despite half the irrigation volume, but is currently unlikely to be adopted by smallholder lowland rice farmers in Nepal, *Food and Energy Security*, 4: 144-157.
<https://doi.org/10.1002/fes3.58>
- Ilahi W., Hassan N., Che'Ya N., Ismail M., Berahim Z., Zakaria N., and Omar M., 2022, Alternate wetting and drying (AWD) on rice irrigation, *Pertanika Journal of Tropical Agricultural Science*, 45(3): 7.
<https://doi.org/10.47836/pjtas.45.3.07>
- Ishfaq M., Farooq M., Zulfiqar U., Hussain S., Akbar N., Nawaz A., and Anjum S., 2020, Alternate wetting and drying: A water-saving and ecofriendly rice production system, *Agricultural Water Management*, 241: 106363.
<https://doi.org/10.1016/j.agwat.2020.106363>
- Liao B., Wu X., Yu Y., Luo S., Hu R., and Lu G., 2020, Effects of mild alternate wetting and drying irrigation and mid-season drainage on CH₄ and N₂O emissions in rice cultivation, *The Science of the Total Environment*, 698: 134212.
<https://doi.org/10.1016/j.scitotenv.2019.134212>
- Majumdar A., Dubey P., Giri B., Moulick D., Srivastava A., Roychowdhury T., Bose S., and Jaiswal M., 2023, Combined effects of dry-wet irrigation, redox changes and microbial diversity on soil nutrient bioavailability in the rice field, *Soil and Tillage Research*, 232: 105752.
<https://doi.org/10.1016/j.still.2023.105752>
- Malumpong C., Ruensuk N., Rossopa B., Channu C., Intarasathit W., Wongboon W., Poathong K., and Kunket K., 2020, Alternate wetting and drying (AWD) in broadcast rice (*Oryza sativa* L.) management to maintain yield, conserve water, and reduce gas emissions in Thailand, *Agricultural Research*, 10: 116-130.
<https://doi.org/10.1007/s40003-020-00483-2>
- Martínez-Eixarch M., Alcaraz C., Guàrdia M., Català-Fornier M., Bertomeu A., Monaco S., Cochrane N., Oliver V., Teh Y., Courtois B., and Price A., 2021, Multiple environmental benefits of alternate wetting and drying irrigation system with limited yield impact on European rice cultivation: the ebre delta case, *Agricultural Water Management*, 258: 107164.
<https://doi.org/10.1016/j.agwat.2021.107164>
- Patikorn S., Amnat C., and Sirintornthep T., 2018, Rice cultivation to cope with drought situation by alternate wet and dry (AWD) water management system: case study of Ratchaburi Province, Thailand, *Chemical engineering transactions*, 63: 139-144.
<https://doi.org/10.3303/CET1863024>
- Reavis C., Reba M., and Runkle B., 2024, The effects of alternate wetting and drying irrigation on water use efficiency in Mid-South rice, *Agricultural and Forest Meteorology*, 353: 110069.
<https://doi.org/10.1016/j.agrformet.2024.110069>
- Song T., Das D., Hu Q., Yang F., and Zhang J., 2020, Alternate wetting and drying irrigation and phosphorus rates affect grain yield and quality and heavy metal accumulation in rice, *The Science of the Total Environment*, 752: 141862.
<https://doi.org/10.1016/j.scitotenv.2020.141862>
- Song T., Xu F., Yuan W., Chen M., Hu Q., Tian Y., Zhang J., and Xu W., 2019, Combining alternate wetting and drying irrigation with reduced phosphorus fertilizer application reduces water use and promotes phosphorus use efficiency without yield loss in rice plants, *Agricultural Water Management*, 223: 105686.
<https://doi.org/10.1016/J.AGWAT.2019.105686>
- Sriphrom P., Chidthaisong A., and Towprayoon S., 2019, Effect of alternate wetting and drying water management on rice cultivation with low emissions and low water used during wet and dry season, *Journal of Cleaner Production*, 223: 980-988.
<https://doi.org/10.1016/J.JCLEPRO.2019.03.212>
- Wijesundara W., 2024, Effect of alternate wetting and drying technique (AWD) on water productivity of paddy in major irrigation schemes-a case study in Mahaweli System B, *Brazilian Journal of Development*, 10(11): e74475.
<https://doi.org/10.34117/bjdv10n11-014>
- Zhang Y., Wang W., Li S., Zhu K., Hua X., Harrison M., Liu K., Yang J., Liu L., and Chen Y., 2023, Integrated management approaches enabling sustainable rice production under alternate wetting and drying irrigation, *Agricultural Water Management*, 281: 108265.
<https://doi.org/10.1016/j.agwat.2023.108265>
- Zhao C., Qiu R., Zhang T., Luo Y., and Agathokleous E., 2024, Effects of alternate wetting and drying irrigation on methane and nitrous oxide emissions from rice fields: a meta-analysis, *Global Change Biology*, 30(12): e17581.
<https://doi.org/10.1111/gcb.17581>



Disclaimer/Publisher's Note

The statements, opinions, and data contained in all publications are solely those of the individual authors and contributors and do not represent the views of the publishing house and/or its editors. The publisher and/or its editors disclaim all responsibility for any harm or damage to persons or property that may result from the application of ideas, methods, instructions, or products discussed in the content. Publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.
